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sensitive to the red rays—the different effects of the colours of the planets might be made apparent.

Perfection of image would not be of so much importance as the effect in producing chemical action on the plate.

To show the possibility of doing this, I beg to lay before the Society two photographic plates, one with a row of pictures of *Jupiter* (showing the effect of a slight difference in the exposure on the image both as to size and density), and the other a picture of *Saturn*, all taken with an exposure of about 2½ seconds in the case of *Saturn*, and still less in the case of *Jupiter*, by an eighteen-inch silver-on-glass Newtonian telescope.

March 1879.

Note on Large Telescopes, with suggestions for mounting Reflectors.

By A. A. Common, Esq.

The question how an increase of telescopic power may be best attained is well worth discussing, and I propose to offer some suggestions how an advance on our present means may be most readily made.

The question turns on the relative capacity of the refracting and reflecting telescope to give this increase,[*] and without attempting to decide which kind will eventually be found best, it is possible, I think, to show that practically the advantage is on the side of the reflector.

Although up to a certain size (taking 26 inches as the largest yet made) the refractor equals or surpasses the reflector in light-grasping power, and has certain advantages in use, as, for instance, the permanence of adjustment, readiness at all times for work, and freedom from great atmospheric disturbance, and, for its disadvantages, great length and chromatic aberration which prevents its complete use in photographic and spectroscopic work; while the reflector has, for its advantages, shorter focal length and total absence of chromatic aberration, and, for its disadvantages, want of permanency of adjustment, greater atmospheric disturbance, and a reflecting surface that requires constant attention and frequent renewal; these advantages and disadvantages do not much affect the question, for it is not on these grounds that it can be decided.

For at this point (viz. a 26-inch refractor or the equivalent sized reflector) the difficulties in producing the two kinds, or, in

[*] Since this paper was drafted and the conditions laid down, I have received from the author, Mr. Howard Grubb, a copy of his paper "On the Great Telescopes of the Future," published in the *Scientific Transactions* of the Royal Dublin Society, a paper I read with much interest, though I do not agree with him on several points. In it this question is most fully discussed; and although the writer does not advocate any particular kind, there is a very decided leaning to the reflector of speculum metal, the reflecting power of which he hopes to be able to improve.

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other words, the cost—for that really represents the various difficulties expressed in terms of pounds, shillings, and pence—is greatly in favour of the reflector; and at that size, or a little above, the production of the refractor may for the present be said to stop, owing to the great difficulty (almost impossibility) of producing the disks of glass of sufficient purity for the purpose of the optician, and of working and supporting the object glass when made; and although these difficulties might by great care and skill be in a manner overcome, there remains the important fact that, owing to the absorption of the light by the glass, which is necessarily thicker as the aperture of the object glass increases, a point is soon reached when the hitherto greater light-grasping power of the refractor is equalled by the reflector, and beyond which it rapidly falls behind the latter, so that it is possible to conceive an object glass so large that it would let but a small fraction of the incident light through. This is of course well known, but it does not seem to have had that effect on the minds of astronomers that we would expect. It certainly does decide it beyond any doubt as far as present conditions hold. We are therefore obliged to turn to the reflector for the purpose in view; and the point then arises, which of the two surfaces—speculum metal or silver—is best for the purpose?

Sir John Herschel, in his book on the *Telescope*, gives for a Newtonian reflector with the mirrors of Lord Rosse's metal, 0·436 as the fraction of incidental light reflected; while, for the like telescope with mirrors of solid silver, he gives 0·824; and, allowing that speculum metal might be improved in reflecting power, and that the surface of silver deposited by chemical action may be less reflective than solid silver, a very large margin is left in favour of the silver-on-glass; and, considering that the mirror of speculum metal has the figure endangered if not destroyed every time it is repolished, while that once given to a glass mirror is permanent, and that there is not any difficulty, as I shall presently show, in producing this surface of silver, no choice is left as to which is best. As to any difficulty in producing glass disks—not necessarily by the glass manufacturer—for the purpose, there would not be more in any case than that met with in producing disks of speculum metal, while the weight would be in favour of the glass.*

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* Mr. Howard Grubb, in the paper already referred to, has dismissed the claims of the silvered glass mirror, in a rather summary manner, in these words:—

"As regards silver-on-glass mirrors, it is hardly worth discussing their relative powers of permanence, as at the present date the art of glass-making has not arrived at that degree of perfection that will permit makers to undertake disks of any kind of suitable glass of six feet diameter; but I may mention that this is perhaps not to be much regretted, as the difficulty of preserving a silvered surface of large size would almost amount to an impossibility, and the process of silvering when the mirror is of large dimensions becomes most formidable; and, finally, it is possible that all the advantages of the silvered glass mirrors, without their corresponding disadvantages, may be secured by

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The principle of mounting, whether Gregorian, Cassegranian, Herschelian, or Newtonian, is, and must be, a matter of taste. When we consider that the Melbourne reflector (the great instance of the Cassegranian principle) has—using, we presume, the large mirror only—produced photographs showing—as some of them do—such detail as the small craters between *Stadius* and *Copernicus*, and as a Cassegranian telescope failed to show the outer satellite of *Mars* at the last opposition, while it was readily seen in England with an 18-inch Newtonian under less favourable conditions, we must come to the conclusion that the principle or its adaptation is somewhere at fault.

But the simplicity of the Newtonian, and the ease with which the adjustments are made, and the favourable position given to the observer, are enough, in my opinion, to make it preferable; although, if very large sizes were attempted, it might be necessary to use the Herschelian principle, or a modification of it, if any great difficulty were found in the making of the flat mirror.

Having, then, by this process of selection got the silver-on-glass reflector on the Newtonian principle, it becomes necessary to consider the mounting; and here we come to what may be regarded as the vital point; for on the proper mounting of the reflector, so as to point it to any object in the heavens, and follow that object in its diurnal motion, while retaining all the conditions that are favourable to the best performance of the optical part, a great deal depends. As far as I know, no endeavour has been made to really find out these favourable conditions and make the mounting suit them, except in a partial manner.

I have endeavoured to find them out, and propose to indicate how they ought to be attained. They are as follows:—

1. No tube properly so called.
2. No mass of metal either below or at the side of the line joining the large and small mirrors.
3. An equatoreal mounting capable of direction to any part of the visible heavens, and of continued observation past the meridian without reversal.
4. An efficient means of supporting the mirror without flexure.
5. Driving clock. Circles to find or identify an object and motions taken to eye end.
6. A collimator for the ready adjustment of the mirrors.

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other means—a matter which I shall speak more of further on"; the other means alluded to being a metal of superior reflecting power. Afterwards, in this paper, he admits that the difficulties in the case of the glass disk might be overcome, as it has been in case of the metal, without the aid of the specialist.

And here I might mention that, if it is a fact that the refractor at 35 inches aperture is equalled by the reflector of speculum metal of that size, it is hardly necessary to speak of disks of optical glass of 40 inches diameter, which when made would not nearly equal the reflector, unless we find some great—at present unknown—advantage in the refractor.

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7. Such a construction of mounting as to give the greatest amount of steadiness with the least amount of friction.

8. An effectual means of resilvering the mirrors and of protecting them from dew.

9. A safe, steady, and easily adjusted platform for the observer, allowing about two hours' continuous observation without the necessity of any motion, except that from the observer's place, and of ready access.

10. A suitable locality for the erection of the telescope.

The first condition, that there shall be no tube, as such, is met by the use of a light, open, braced framing, by preference square, and which, by the use of steel tubes and rods, could be made of the required rigidity with extreme lightness. The second condition, that there shall not be any mass of metal between the large and small mirrors, is, like the first, aimed at the reduction of the atmospheric disturbance. To point out what is meant, we may take, as an example of what under these conditions would be considered the worst possible way to mount a reflector, that shown on page 134 of Newcomb's *Popular Astronomy*; and, as an approach to the best, that of the Melbourne reflector, supposing the mirror at that part where the diagonal bracing begins, and above the declination axis. The third condition indicates as the position of the mirror some point symmetrically above the polar axis, as in the mounting of Mr. Lassell's 4-foot telescope; but with this difference, that the polar axis would not be forked, but come directly under that part of the mounting bearing the mirror, and be sufficiently prolonged above the upper bearing or neck to allow a forked counterpoise to the framework necessary to carry the small mirror. The fourth condition has been so well met in the Melbourne telescope in the case of a heavy metal speculum, that it could not fail to do with glass; though something more simple might possibly be found to answer with this material in large sizes, as it has been found to answer perfectly with 18 inches. The plan suggested is this: the three primary levers bear at their extremities, instead of the secondary and tertiary systems, six flat plates, so made as to present for a bearing a broad ring, and so large as to form a circle of rings or plates almost touching and each coming under the mirror; so that, if it is conceived to be divided into six triangles by radial lines at equal distances, a ring would be under each, almost touching the straight sides; while for edge suspension three flat metal bands are connected to three equidistant points about one-twelfth of the diameter from the edge of the mirror, and each band going two-thirds of the way round the mirror.

The fifth and sixth conditions offer no difficulty. The seventh condition as regards stability is easily met, and as regards the friction, particularly as to the movement in right ascension, there is a way, by the use of the floating power of mercury, to so take off the weight from the bearing by making the polar axis of cast iron, hollow and cylindrical, and of sufficient length and

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size to displace the requisite quantity of mercury (placed in another cylinder, slightly larger, in which the polar axis will turn) to reduce it to any amount. The eighth condition as regards the silvering of the glass surface is not so difficult to meet as might have been expected; as it has been found quite practicable to silver an 18-inch mirror by simply putting a band of suitable material round the edge, so as to form a dish with the mirror as the bottom, pouring in the solutions properly filtered, and allowing the silver to deposit, thereby getting a really good film, we need not anticipate that there would be any difficulty with large sizes. As to protecting the mirrors from dew when a mirror is uncovered for a night's work, the temperature of the air, as a rule, falling more rapidly than the mirror parts with its heat, prevents dewing, and it is only necessary to have some covering vertically above to prevent the dew actually falling on the mirror. A screen for this purpose could be made and used without destroying the first condition. The ninth condition is of great importance to the observer. There is nothing in my opinion which would equal an arrangement similar to the altazimuth mounting of Herschel's largest telescope revolving round the Equatoreal, but of course quite detached therefrom, with such a width of platform as to give say two hours' observation on the meridian, and either with the sloping sides for the platform to work on, or with sides curved to such a radius as to keep the platform a constant distance from the telescope at any elevation. Such a platform properly counterpoised would be safe, steady, and easily accessible by a ladder or stairs, while the open character of the structure is not unfavourable to the telescope.

The last condition being beyond the scope of this paper, and involving considerations of such a different character, I propose to leave it for independent discussion at some future time.

March 31, 1879.

On some Formulæ for expressing the value of the Excentric Anomaly etc. in terms of the Mean Anomaly. By M. A. De Gasparis.

Il peut être utile, pour le calcul des perturbations, d'exprimer la valeur de l'anomalie excentrique, vraie, du rayon vecteur, des coordonnées héliocentriques, etc., en fonction de l'anomalie moyenne, donnée en parties du rayon. J'ai trouvé les formules suivantes :—

$$E = \frac{M}{1-e} - \frac{M^3}{6}\frac{e}{(1-e)^4} + \frac{M^5}{120}\frac{e+9e^2}{(1-e)^7} - \frac{M^7}{5040}\frac{e+54e^2+225e^3}{(1-e)^{10}} \cdots$$

$$(1-e^2)^{-\frac{1}{2}} \sin v = \frac{M}{1}\frac{1}{(1-e)^2} - \frac{M^3}{6}\frac{1+3e}{(1-e)^5} + \frac{M^5}{120}\frac{1+24e+45e^2}{(1-e)^8} - \frac{M^7}{5040}\frac{1+97e+947e^2+1755e^3}{(1-e)^{11}} \cdots$$